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(54) **ADVANCED CATALYSTS FOR AUTOMOTIVE APPLICATIONS**

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(58) **Field of Classification Search**

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See application file for complete search history.

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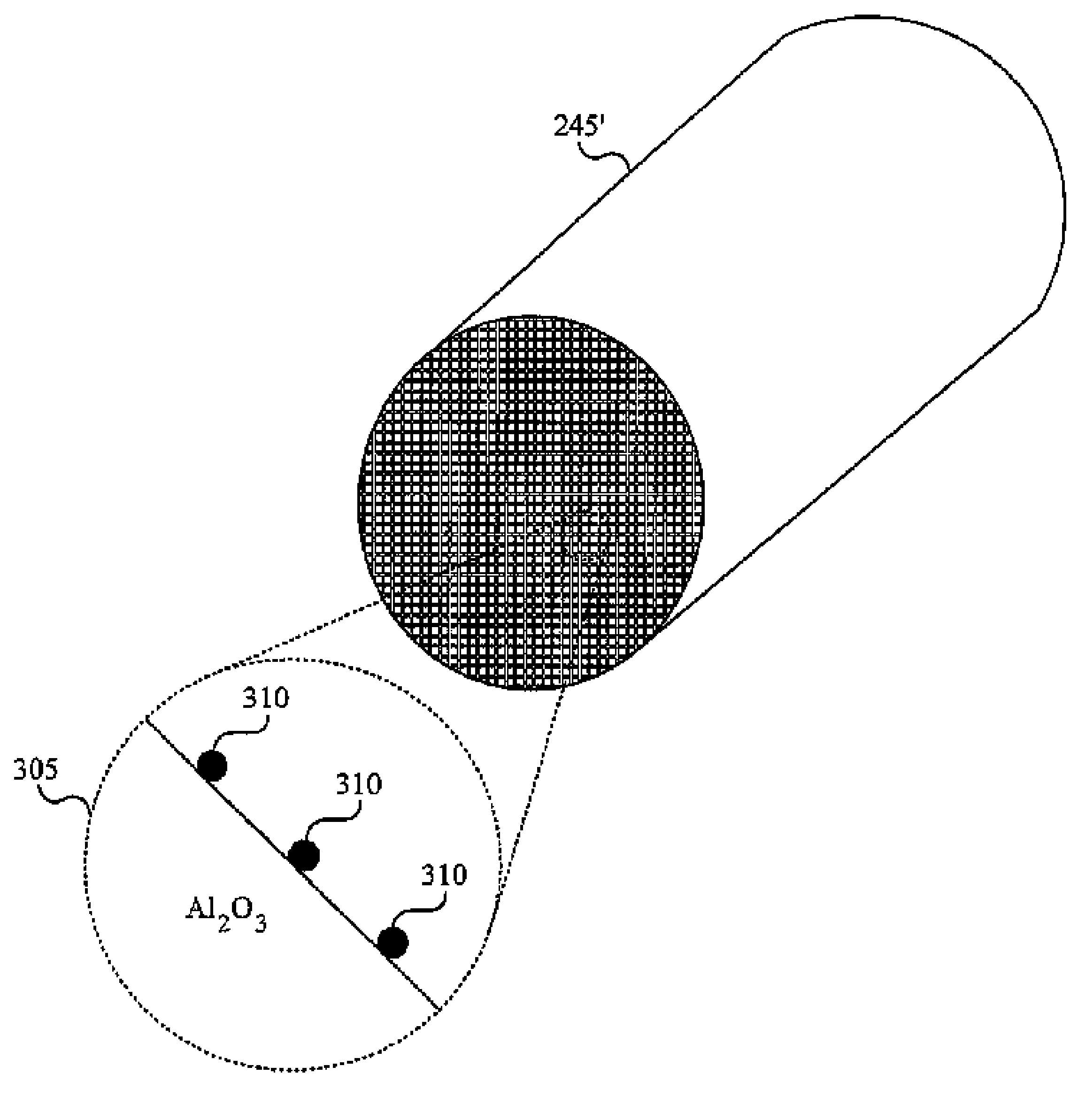
(57) **ABSTRACT**

Embodiments of present inventions are directed to an advanced catalyst. The advanced catalyst includes a honeycomb structure with an at least one nano-particle on the honeycomb structure. The advanced catalyst used in diesel engines is a two-way catalyst. The advanced catalyst used in gas engines is a three-way catalyst. In both the two-way catalyst and the three-way catalyst, the at least one nano-particle includes nano-active material and nano-support. The nano-support is typically alumina. In the two-way catalyst, the nano-active material is platinum. In the three-way catalyst, the nano-active material is platinum, palladium, rhodium, or an alloy. The alloy is of platinum, palladium, and rhodium.

31 Claims, 10 Drawing Sheets



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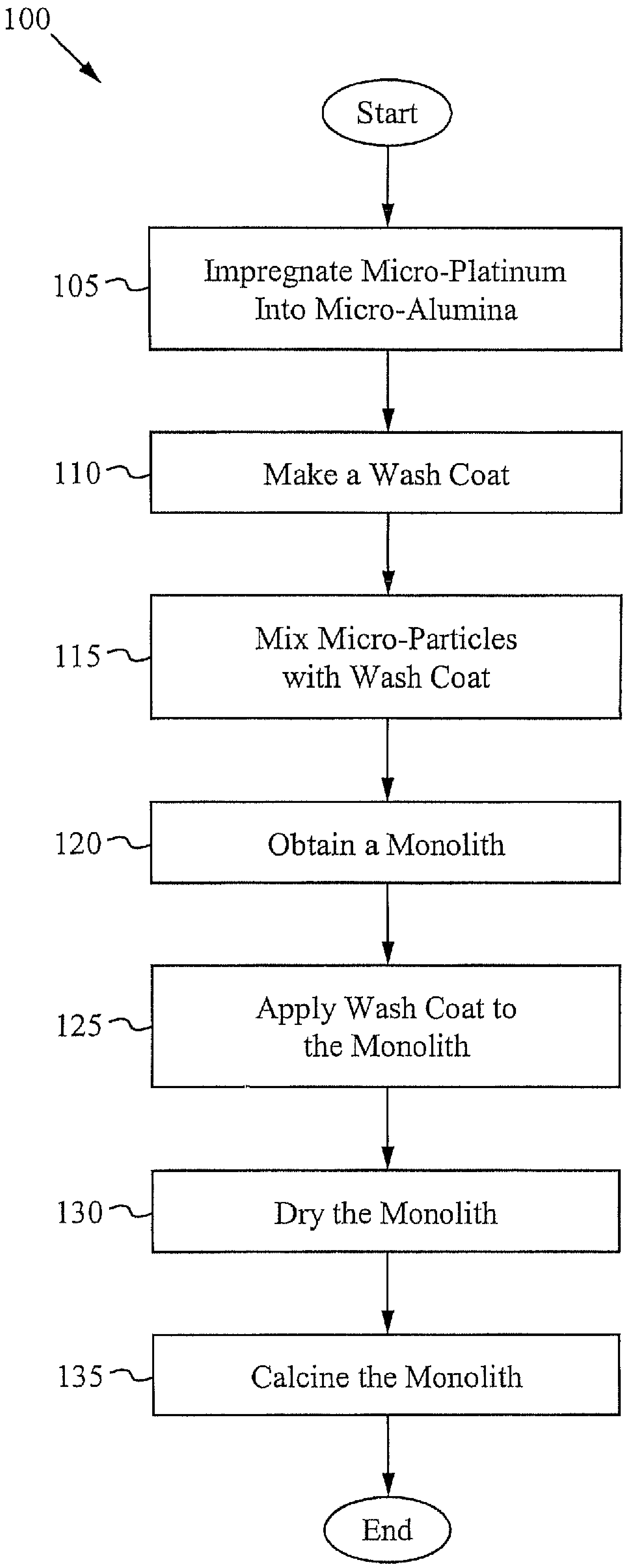
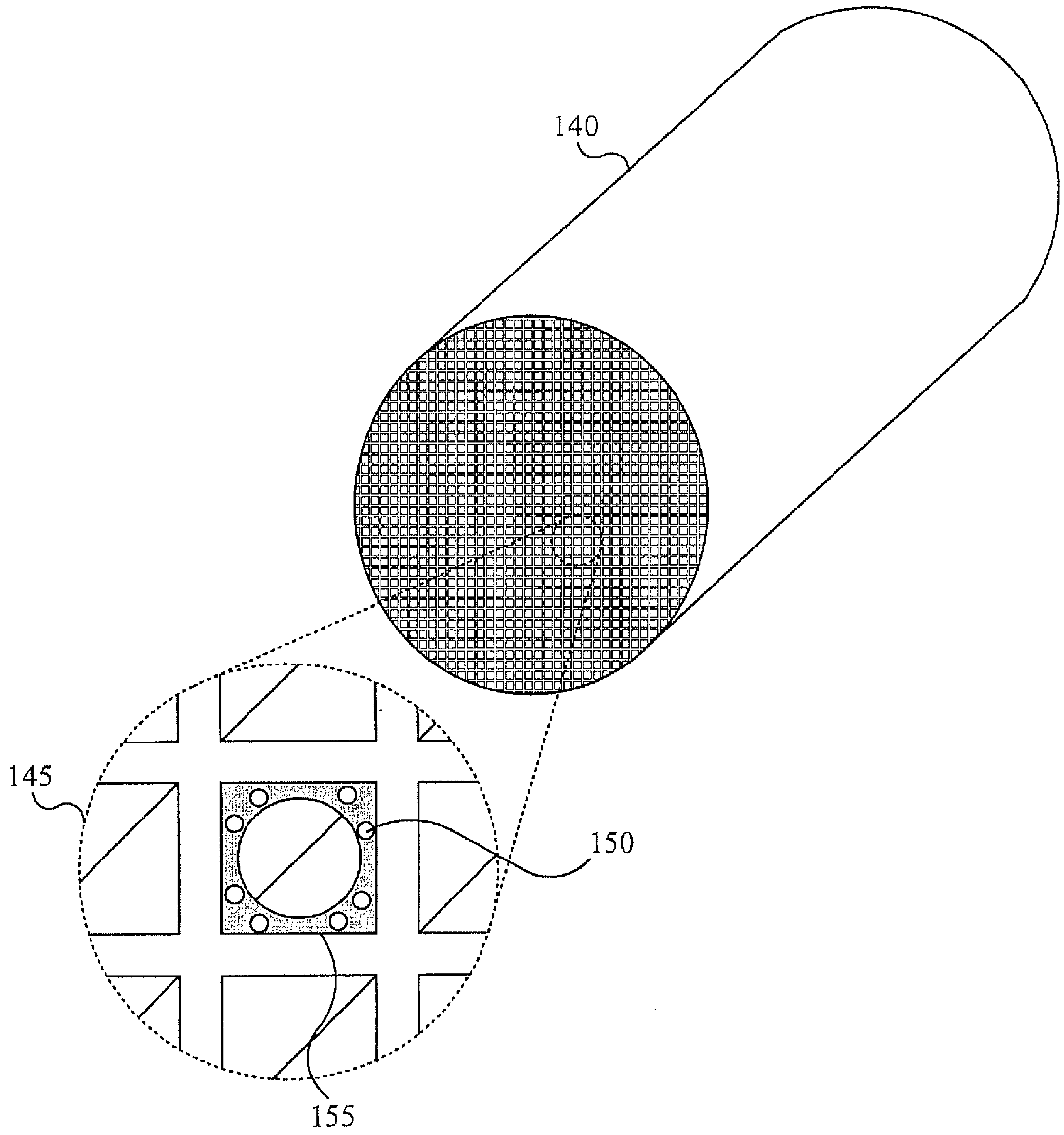


Fig. 1A (Prior Art)



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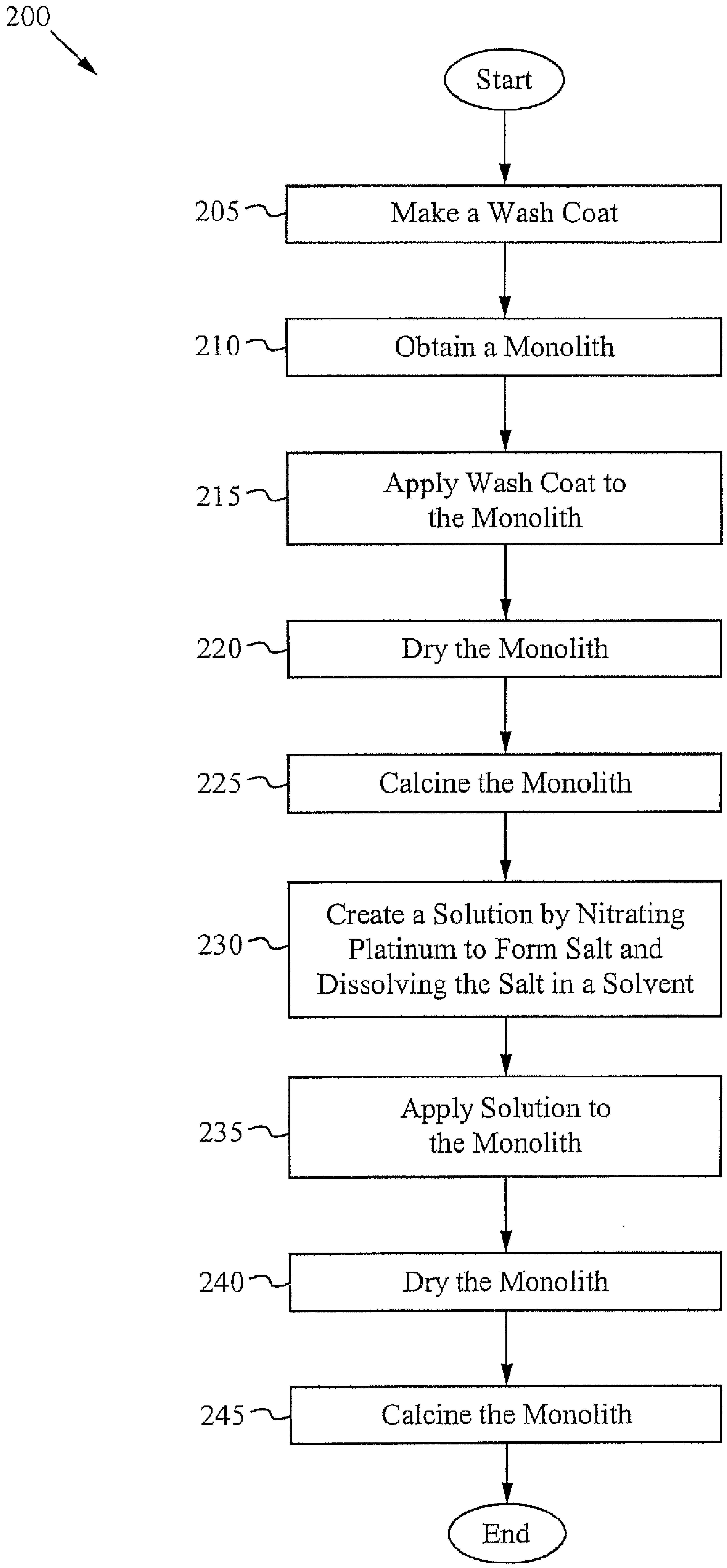

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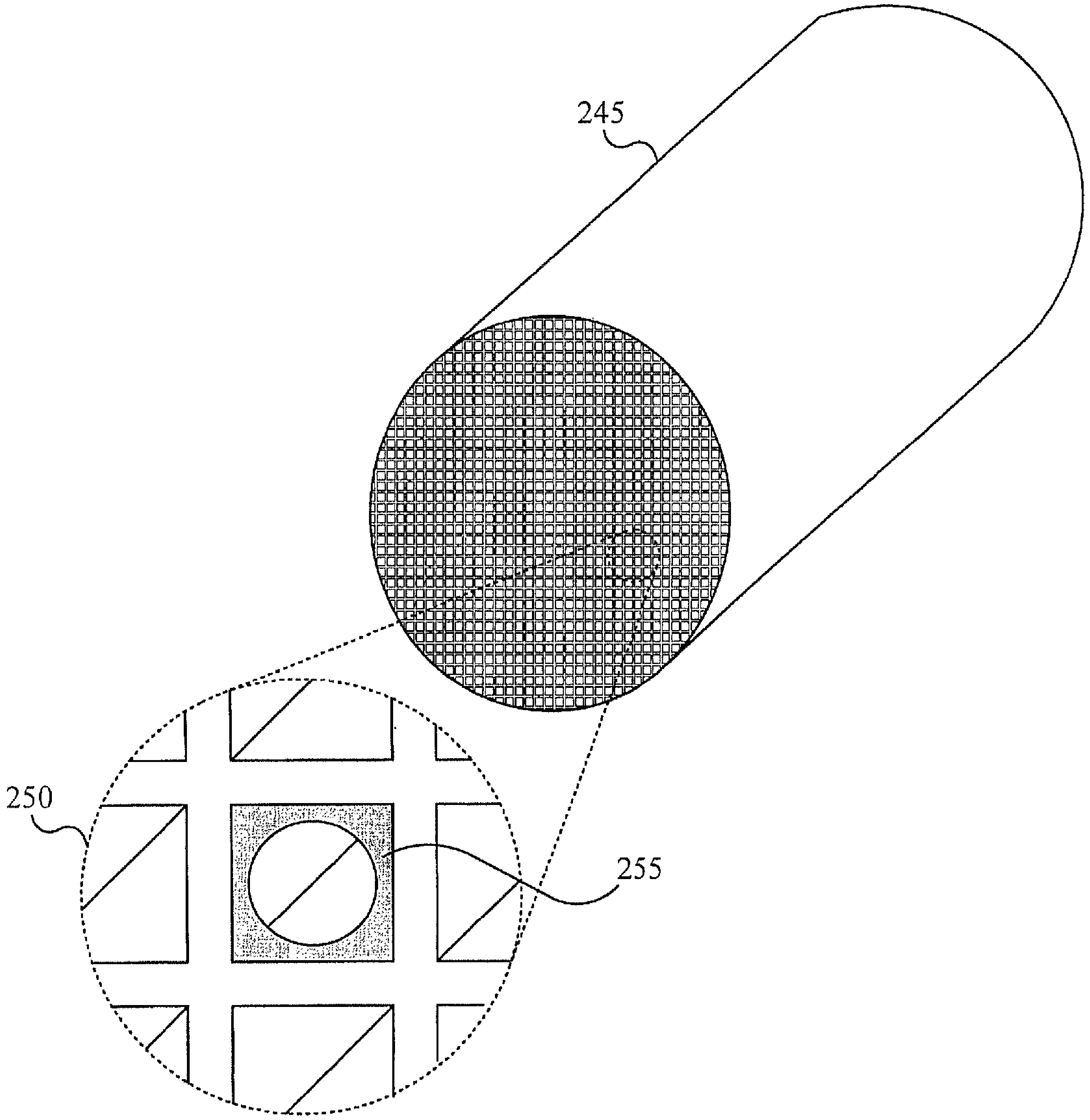

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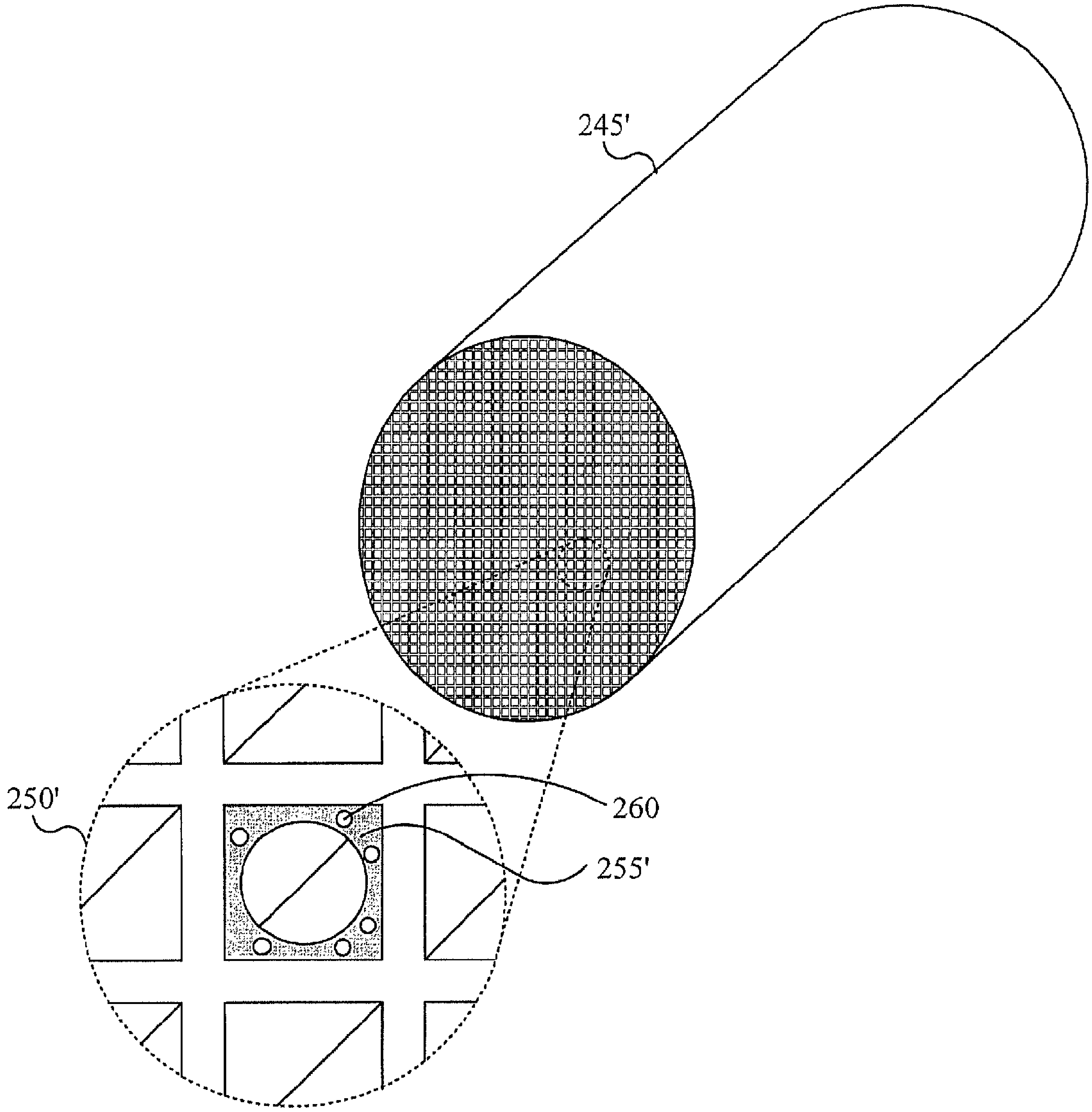

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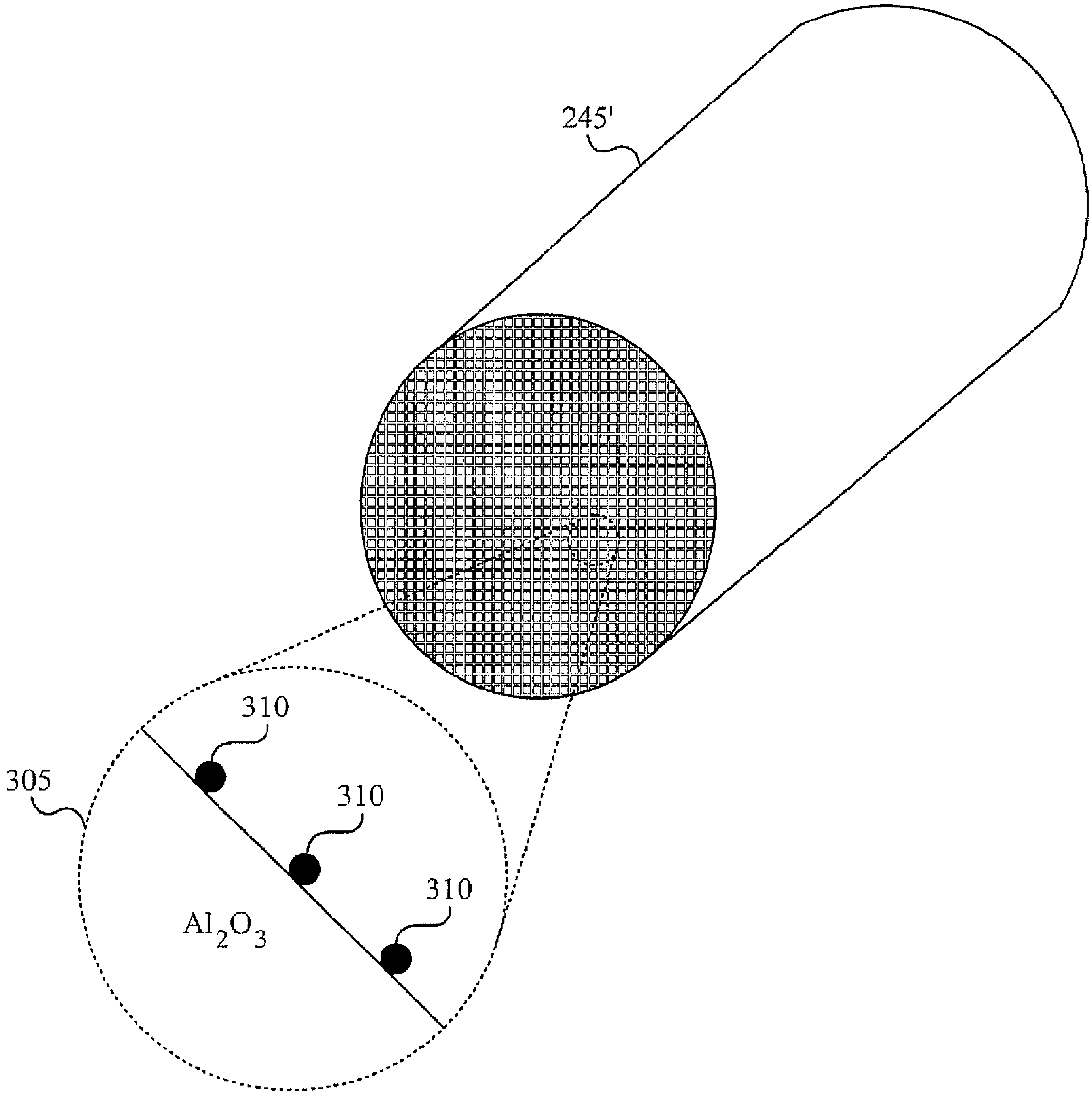
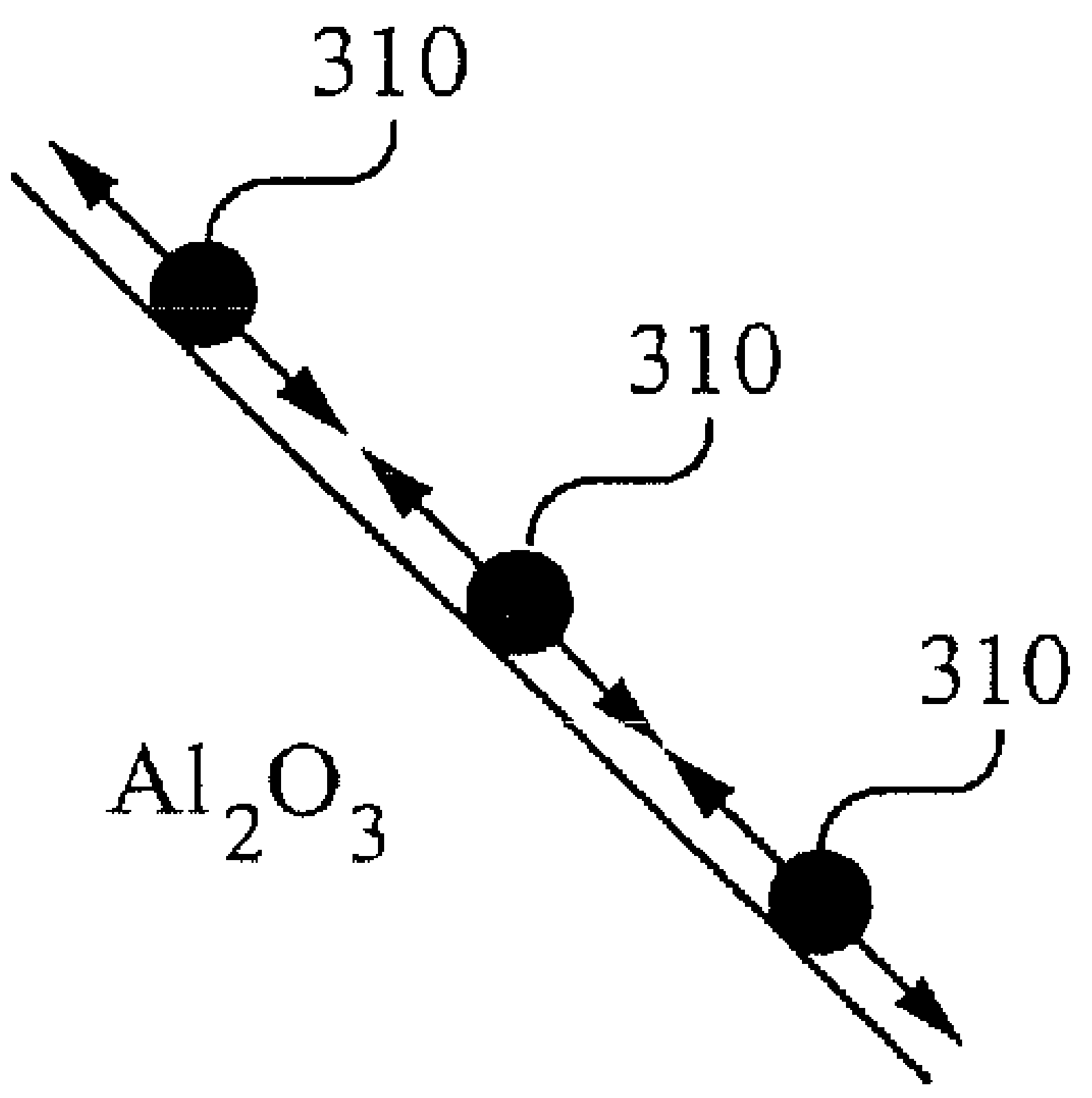


Fig. 3A



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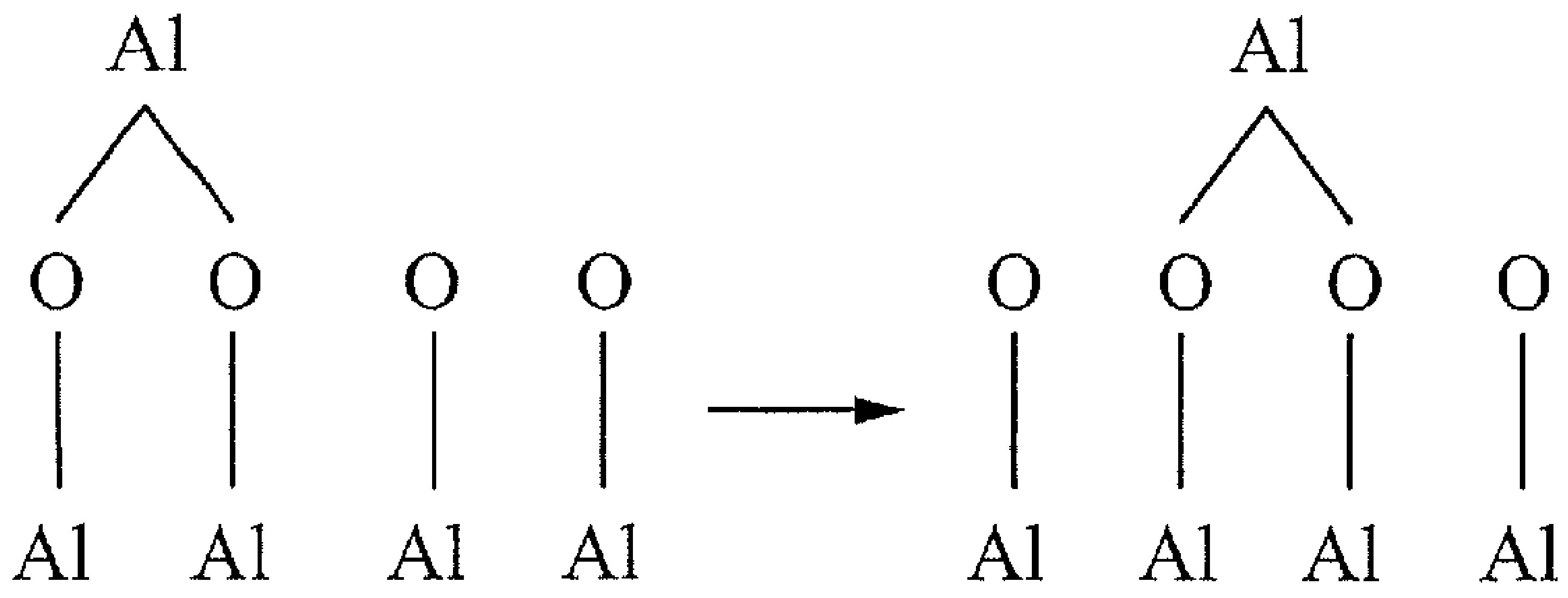

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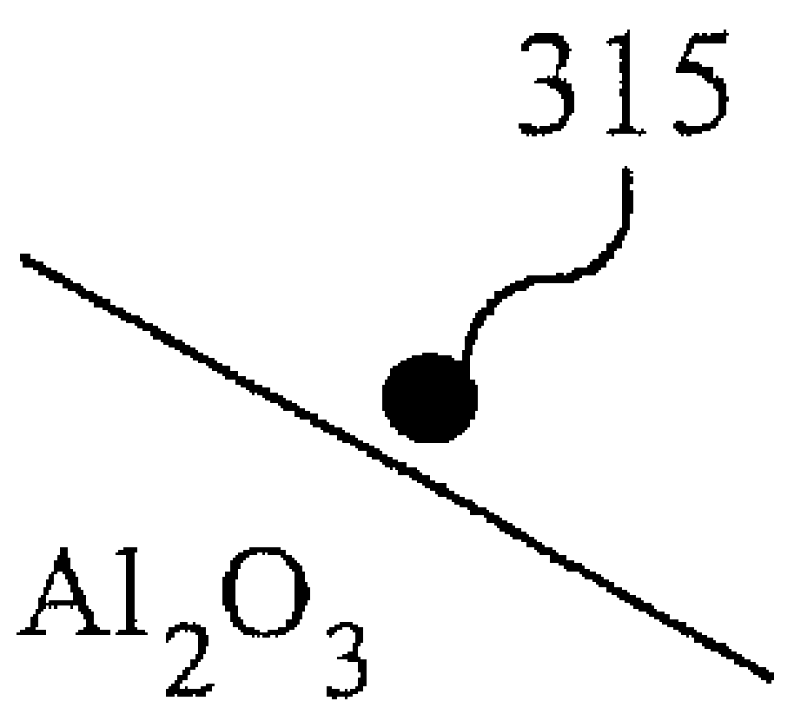

Fig. 3D

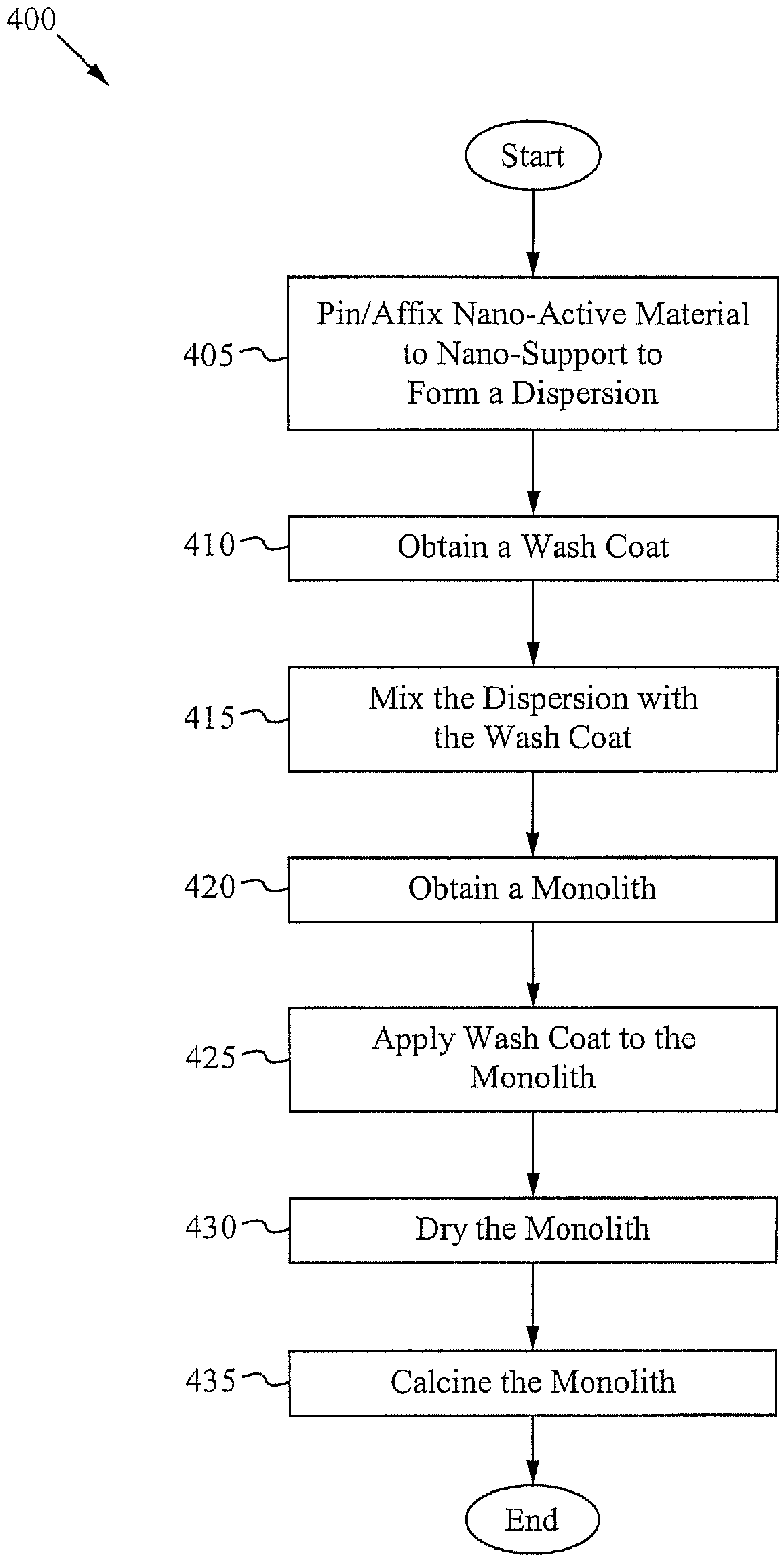
400
Start
405
Pin/Affix Nano-Active Material to Nano-Support to Form a Dispersion
410
Obtain a Wash Coat
415
Mix the Dispersion with the Wash Coat
420
Obtain a Monolith
425
Apply Wash Coat to the Monolith
430
Dry the Monolith
435
Calcine the Monolith
End

Fig. 4

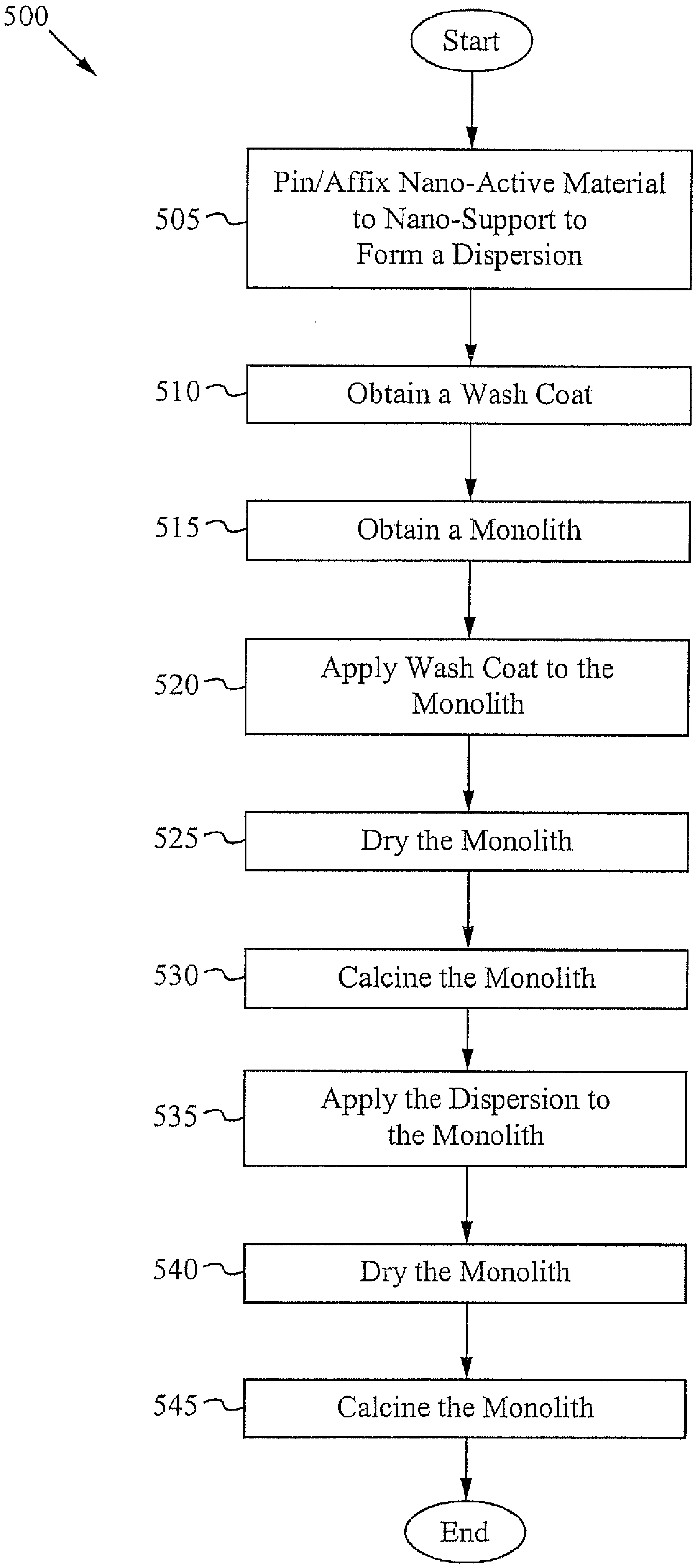
500
Start
505
Pin/Affix Nano-Active Material to Nano-Support to Form a Dispersion
510
Obtain a Wash Coat
515
Obtain a Monolith
520
Apply Wash Coat to the Monolith
525
Dry the Monolith
530
Calcine the Monolith
535
Apply the Dispersion to the Monolith
540
Dry the Monolith
545
Calcine the Monolith
End

Fig. 5

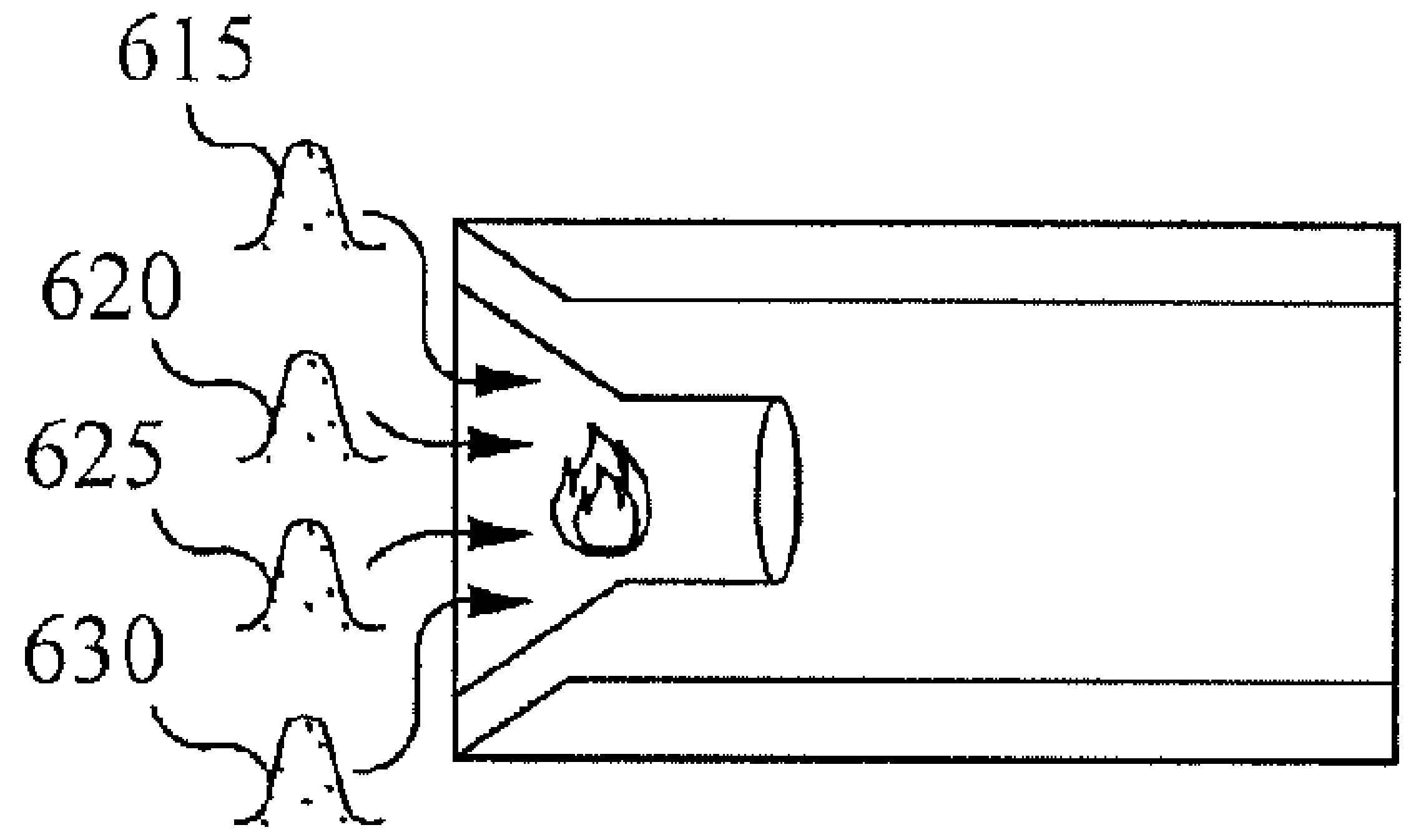

Fig. 6A

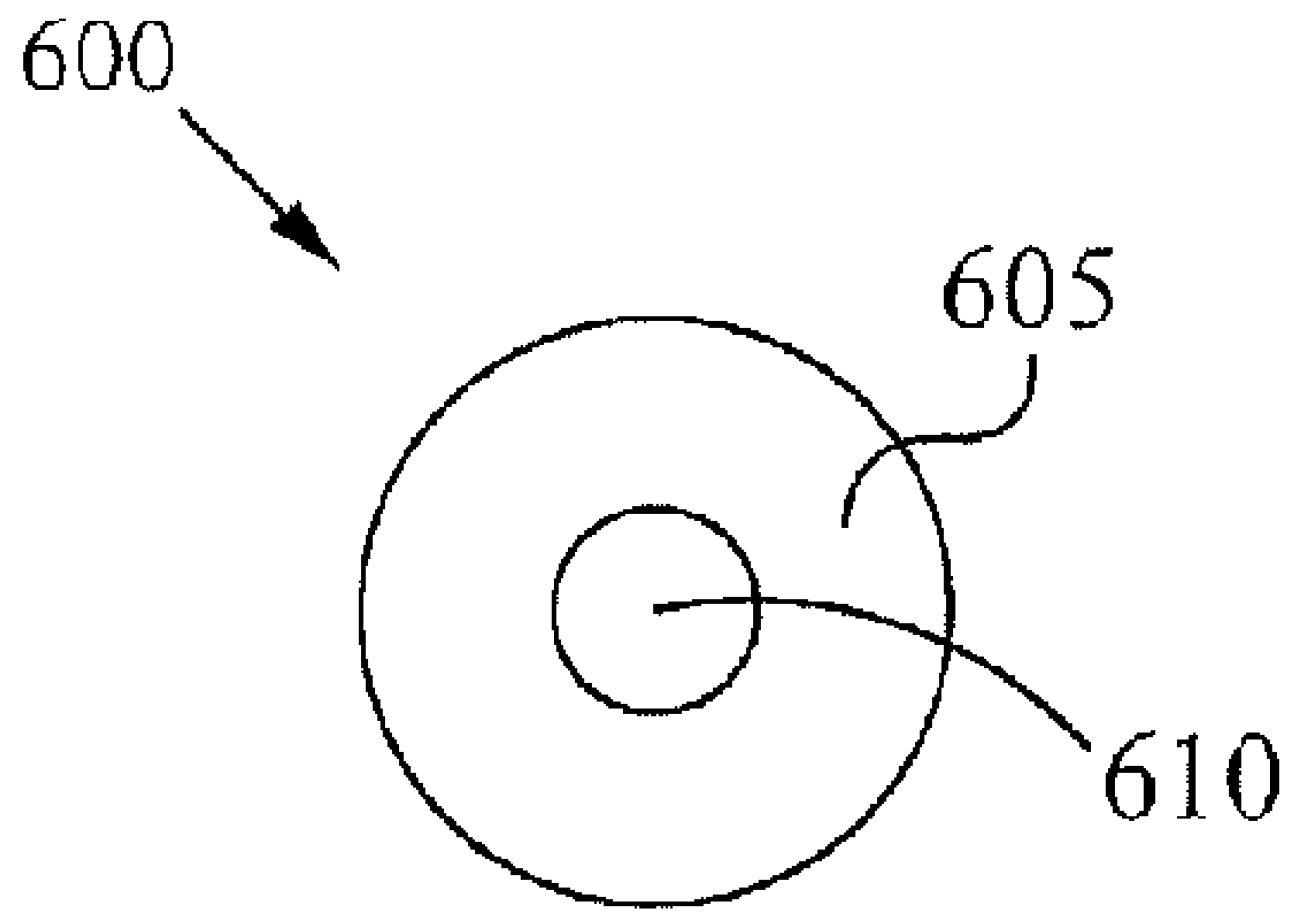

Fig. 6B

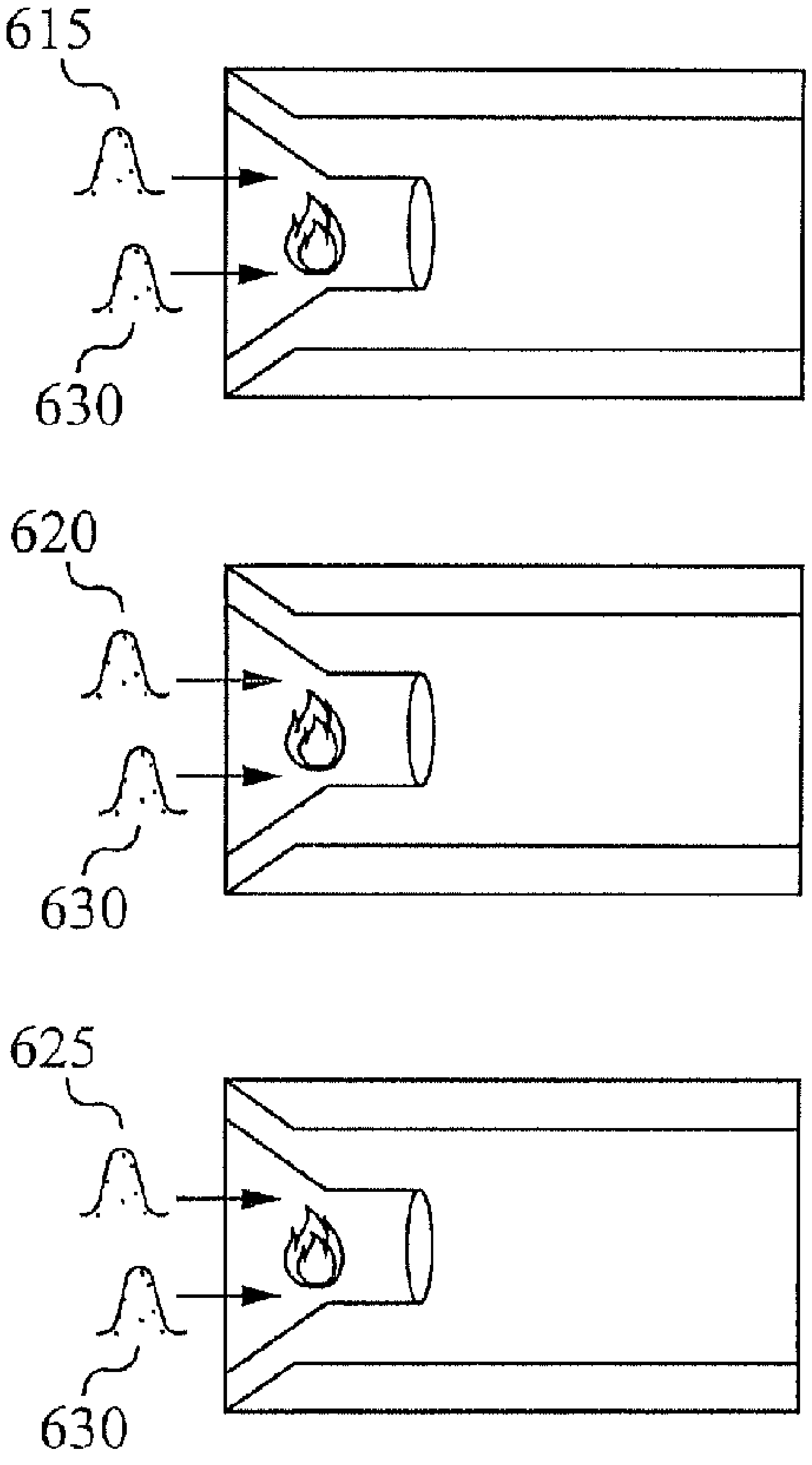

Fig. 7A

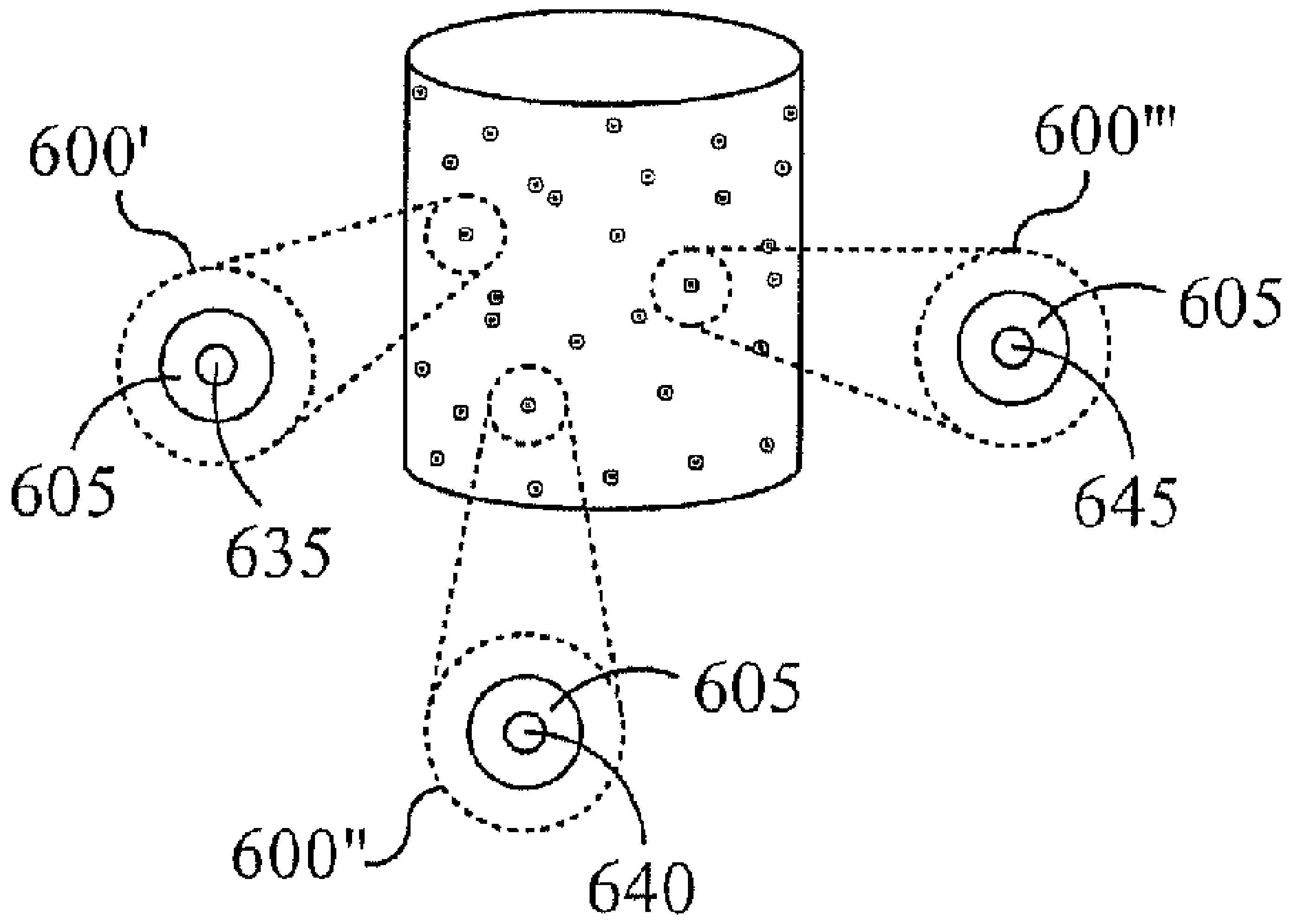

Fig. 7B

ADVANCED CATALYSTS FOR AUTOMOTIVE APPLICATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application Ser. No. 61/284,329, filed Dec. 15, 2009 and entitled "MATERIALS PROCESSING," which is hereby incorporated herein by reference in its entirety as if set forth herein.

BACKGROUND OF THE INVENTION

A catalytic converter for a car uses a catalyst to convert, for example, three harmful compounds in car exhaust into less harmful compounds. The three harmful compounds include hydrocarbons in the form of unburned gasoline, carbon monoxide formed by the combustion of gasoline, and nitrogen oxide created when heat in the engine forces nitrogen in the air to combine with oxygen. There are two main structures used in catalytic converters—honeycomb and ceramic beads. Most automobiles today use the honeycomb structure. The honeycomb structure is housed in a muffler-like package that comes before the exhaust pipe. The catalyst helps to convert carbon monoxide into carbon dioxide, the hydrocarbons into carbon dioxide and water, and the nitrogen oxides back into nitrogen and oxygen.

Various methods of manufacturing the catalyst used in the catalytic converter exist in the art. FIG. **1**A illustrates a first conventional method of manufacturing the catalyst. The first method is known as a one-dip process. At a step **105**, micron-sized platinum (Pt) ions are impregnated into micron-sized alumina (Al_2O_3) ions, resulting in micro-particles. The micro-particles have platinum atoms on the alumina ions. At a step **110**, a wash coat is made using micron-sized oxides that include pint size alumina and pint size silica (SiO_2), a certain amount of stabilizers for the alumina, and a certain amount of promoters. At a step **115**, the micro-particles are mixed together with the wash coat. At a step **120**, a cylindrical-shaped ceramic monolith is obtained. A cross-section of the monolith contains 300-600 channels per square inch. The channels are linear square channels that run from the front to the back of the monolith. At a step **125**, the monolith is coated with the wash coat. This can be achieved by dipping the monolith in the wash coat. As such, the channels of the monolith are coated with a layer of wash coat. At a step **130**, the monolith is dried. The layer of wash coat has an irregular surface, which has a far greater surface area than a flat surface. In addition, the wash coat when dried is a porous structure. The irregular surface and the porous structure are desirable because they give a high surface area, approximately 100-250 m^2/g, and thus more places for the micro-particles to bond thereto. As the monolith dries, the micro-particles settle on the surface and pores of the monolith. At a step **135**, the monolith is calcined. The calcination bonds the components of the wash coat to the monolith by oxide to oxide coupling. The catalyst is formed. FIG. **1**B illustrates a microscopic view **145** of a channel of the monolith **140** that is coated with the layer of wash coat **150** having platinum atoms **155**.

FIG. **2**A illustrates a second conventional method of manufacturing the catalyst. The second method is known as a two-dip process. At a step **205**, a wash coat is made using micron-sized oxides that include pint size alumina and pint size silica, a certain amount of stabilizers for the alumina, and a certain amount of promoters. At a step **210**, a cylindrical-shaped ceramic monolith is obtained. At a step **215**, the monolith is coated with the wash coat such as via dipping. As such, the channels are also coated with a layer of wash coat. Typically, the layer of wash coat has an irregular surface which has a far greater surface area than a flat surface. FIG. **2**B illustrates a microscopic view **250** of a channel of the monolith **245** coated with the layer of the wash coat **255**. Returning to FIG. **2**A, at a step **220**, the monolith is dried. The wash coat when dried is a porous structure. At a step **225**, the monolith is calcined. The calcination bonds the components of the wash coat to the monolith by oxide to oxide coupling. Micron-sized alumina oxides are then impregnated with micron-sized platinum ions and other promoters using a method that is well known in the art. Specifically, at a step **230**, platinum is nitrated, forming salt ($PtNO_3$). The $PtNO_3$ is dissolved in a solvent such as water, thereby creating a dispersion. At step **235**, the monolith is dipped into the solution. At a step **240**, the monolith is dried. At a step **245**, the monolith is calcined. The catalyst is formed. FIG. **2**C illustrates another microscopic view **250'** of the channel of the monolith **245'** coated with the layer of wash coat **255'** having platinum atoms **260**.

FIG. **3**A illustrates a microscopic view **305** of a surface of the layer of the wash coat after calcination. Platinum atoms **310** are attached to oxygen atoms of the alumina. When exhaust gas goes through the catalytic converter, the platinum atoms **310** help reduce the harmful compounds by converting them into less harmful compounds. However, these various methods of manufacturing the catalyst used in the catalytic converter suffer from a number of shortcomings. For example, the platinum atoms **310** are not fixed to their bonded oxygen atoms of the alumina and are able to move around to other available oxygen atoms as illustrated in FIGS. **3**B-**3**C. As the platinum atoms **310** move, the platinum atoms **310** begin to coalesce with other platinum atoms resulting in larger particles **315**, as shown in FIG. **3**D, and a more energetically favorable state. It is understood that as the platinum particles become larger, it detrimentally affects the catalyst since surface area of the platinum atoms decreases. In high temperature applications, such as in an aged catalytic converting testing, the movement of platinum atoms is magnified. In addition, since cost of platinum is extremely expensive, excessive use of platinum is unwanted.

The present invention addresses at least these limitations in the prior art.

SUMMARY OF THE INVENTION

In one aspect, a catalytic converter includes a honeycomb structure with an at least one nano-particle on the honeycomb structure. In some embodiments, the at least one nano-particle includes nano-active material and nano-support. The nano-active material is typically on the nano-support. The nano-active material is platinum, palladium, rhodium, or an alloy. The alloy is of platinum, palladium, and rhodium. The nano-support is alumina. In other embodiments, the nano-support includes a partially reduced alumina surface, which limits movement of the nano-active material on a surface of the nano-support.

In another aspect, a cordierite substrate in a catalytic converter includes a first type of nano-particles, a second type of nano-particles, and a third type of nano-particles. In some embodiments, the first type of nano-particles includes nano-active material and nano-support. The nano-active material is platinum and the nano-support is alumina. The nano-support includes a partially reduced alumina surface, which limits movement of the nano-active material on a surface of the nano-support. In other embodiments, the second type of nano-particles comprises nano-active material and nano-support. The nano-active material is palladium and the nano-support is alumina. The nano-support includes a partially reduced alumina surface, which limits movement of the nano-active material on a surface of the nano-support. In other embodiments, the third type of nano particles comprises nano-active material and nano-support. The nano-active material is rhodium and the nano-support is alumina. The nano-support includes a partially reduced alumina surface, which limits movement of the nano-active material on a surface of the nano-support.

Yet, in another aspect, a method of making a catalytic converter includes creating a dispersion using an at least one nano-particle and obtaining a wash coat. In some embodiments, the at least one nano-particle includes nano-active material and nano-support. The nano-active material is platinum, palladium, rhodium, or an alloy. The nano-support is alumina. The nano-support includes a partially reduced alumina surface, which limits movement of the nano-active material on a surface of the nano-support. In other embodiments, the creating step comprises mixing a carrier material and different catalyst materials in a high temperature condensation technology, thereby producing the at least one nano-particle, and combining it with a liquid. The carrier material is alumina. The different catalyst materials include platinum, palladium, and rhodium. Typically, the high temperature condensation technology is plasma. Alternatively, the creating step comprises mixing a carrier material and a first catalyst material in a high temperature condensation technology, thereby producing a first type of nano-particles, mixing the carrier material and a second catalyst material in the high temperature condensation technology, thereby producing a second type of nano-particles, mixing the carrier material and a third catalyst material in the high temperature condensation technology, thereby producing a third type of nano-particles, collecting together the first type of nano-particles, the second type of nano-particles, and a third type of nano-particles, and combining with a liquid. The carrier material is alumina. The first catalyst material is platinum. The second catalyst material is palladium. The third catalyst material is rhodium.

Yet, in other embodiments, the method of making a catalytic converter further includes mixing the dispersion with the wash coat, applying the mix to a monolith, drying the monolith, and calcining the monolith. Alternatively, the method of making a catalytic converter further includes applying the wash coat to a monolith, drying the monolith, calcining the monolith, administering the dispersion to the monolith, drying the monolith, and calcining the monolith.

Yet, in another aspect, a method of making a three-way catalytic converter includes creating a dispersion by using different types of nano-particles, obtaining a wash coat, mixing the dispersion with the wash coat, applying the mix to a monolith, drying the monolith, and calcining the monolith. The creating step includes using a high temperature condensation technology. In some embodiments, the high temperature condensation technology is plasma. Each of the different types of nano-particles comprises nano-active material and nano-support. The nano-active material is platinum, palladium, rhodium, or an alloy. The nano-support is alumina. The nano-support includes a partially reduced alumina surface, which limits movement of the nano-active material on a surface of the nano-support.

Yet, in another aspect, a method of making a three-way catalytic converter includes creating a dispersion using different types of nano-particles, obtaining a wash coat, applying the wash coat to a monolith, drying the monolith, calcining the monolith, administering the dispersion to the monolith, drying the monolith, and calcining the monolith. The creating step includes using a high temperature condensation technology. In some embodiments, the high temperature condensation technology is plasma. Each of the different types of nano-particles includes nano-active material and nano-support. The nano-active material is platinum, palladium, rhodium, or an alloy. The nano-support is alumina. The nano-support includes a partially reduced alumina surface, which limits movement of the nano-active material on a surface of the nano-support.

Yet, in another aspect, a method of making a two-way catalytic converter includes creating a dispersion by using same type of nano-particles, obtaining a wash coat, mixing the dispersion with the wash coat, applying the mix to a monolith, drying the monolith, and calcining the monolith. The creating step includes using a high temperature condensation technology. In some embodiments, the high temperature condensation technology is plasma. Each of the same type of nano particles includes nano-active material and nano-support. The nano-active material is platinum. The nano-support is alumina. The nano-support includes a partially reduced alumina surface, which limits movement of the nano-active material on a surface of the nano-support.

Yet, in another aspect, a method of making a two-way catalytic converter includes creating a dispersion using same type of nano-particles, obtaining a wash coat, applying the wash coat to a monolith, drying the monolith, calcining the monolith, administering the dispersion to the monolith, drying the monolith, and calcining the monolith. The creating step includes using a high temperature condensation technology. In some embodiments, the high temperature condensation technology is plasma. Each of the same type of nano-particles includes nano-active material and nano-support. The nano-active material is platinum. The nano-support is alumina. The nano-support includes a partially reduced alumina surface, which limits movement of the nano-active material on a surface of the nano-support.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A-**1**B illustrate a first conventional method of manufacturing a catalyst.

FIGS. **2**A-**2**C illustrate a second conventional method of manufacturing the catalyst.

FIGS. **3**A-**3**C illustrate activity on a surface of a layer of wash coat on the monolith using the first conventional method and the second conventional method.

FIG. **3**D illustrates platinum atoms coalesced into a large particle.

FIG. **4** illustrates a first inventive process of creating an advanced catalyst in accordance with the present invention.

FIG. **5** illustrates a first inventive process of creating an advanced catalyst in accordance with the present invention.

FIG. **6**A illustrates a first method of creating a dispersion in accordance with the present invention.

FIG. **6**B illustrates a nano-particle in accordance with the present invention.

FIG. **7**A illustrates a second method of creating a dispersion in accordance with the present invention.

FIG. **7**B illustrates a collection of different nano-particles in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to implementations of the present invention as illustrated in the accompanying drawings. The drawings may not be to scale. The same reference indicators will be used throughout the drawings and the following detailed description to refer to identical or like elements. In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application, safety regulations and business related constraints, and that these specific goals will vary from one implementation to another and from one developer to another. Moreover, it will be appreciated that such a development effort will be a routine undertaking of engineering for those of ordinary skill in the art having the benefit of this disclosure.

The following description of the invention is provided as an enabling teaching which includes the best currently known embodiment. One skilled in the relevant arts, including but not limited to chemistry, physics and material sciences, will recognize that many changes can be made to the embodiment described, while still obtaining the beneficial results of the present invention. It will also be apparent that some of the desired benefits of the present invention can be obtained by selecting some of the features of the present invention without utilizing other features. Accordingly, those who work in the art will recognize that many modifications and adaptations to the present inventions are possible and may even be desirable in certain circumstances, and are a part of the present invention. Thus, the following description is provided as illustrative of the principles of the present invention and not in limitation thereof, since the scope of the present invention is defined by the claims.

Harmful compounds from internal combustion engines include carbon monoxide (CO), hydrocarbons (H_aC_b), and oxides of nitrogen (NO_x). Two forms of internal combustion engines are diesel engines and gas engines. A catalytic converter is designed to reduce these harmful compounds by converting them into less harmful compounds. As discussed above, conventional catalysts used in catalytic converters use micro-particles such as micron-sized oxides and micron-sized catalyst materials (e.g. platinum). Embodiments of the present invention use nano-sized oxides and nano-sized catalyst materials to create advanced catalysts usable in catalytic converters of diesel engines and gas engines.

The term "nano-particle" is generally understood by those of ordinary skill to encompass a particle having a diameter in the order of nanometers, as described herein.

Diesel Engines

A diesel engine includes a diesel oxidation catalyst (DOC), a separate NOx reduction technology, and a diesel particulate filter (DPF). The DOC is a two-way catalytic converter, which converts (1) CO and O_2 to CO_2 and (2) H_aC_b and O_2 to CO_2 and H_2O. The DOC uses platinum as an oxidizing agent. Conventional methods of creating the DOC use micron-size platinum ions. Embodiments of the present invention use nano-sized platinum particles instead. FIGS. **4**-**5** illustrate two inventive processes of creating an advanced DOC catalyst in accordance with the present invention. The separate NOx reduction technology reduces the NO_x emissions by using urea as a reducing agent. The DPF catches subparticles (e.g. nongaseous hydrocarbons) from an exhaust gas of the diesel engine.

FIG. **4** illustrates a first inventive process **400** for creating the advanced DOC catalyst in accordance with the present invention. At a step **405**, nano-active materials are pinned or affixed to nano-supports, forming nano-particles, by using a high temperature condensation technology such as a plasma gun. In some embodiments, the nano-active materials are gaseous platinum atoms, and the nano-supports are some form of alumina, such as aluminum plus oxygen. For the sake of brevity, platinum will be discussed herein, but it will be apparent to those of ordinary skill in the art that different platinum group metals can be used to take advantage of their different properties. Since nano-active materials are strongly attached to nano-supports, movement or coalescing/conglomeration of the nano-active materials is limited, prevented, or both. The nano-particles are then combined with a liquid to form a dispersion. The nano-particles and the dispersion are created using methods described in detail in U.S. patent application Ser. No. 12/001,643, filed Dec. 11, 2007, which is hereby incorporated by reference. At a step **410**, a wash coat is obtained. The wash coat is commercially purchased or is made. Typically, the wash coat is a slurry. The wash coat is made by using micron-sized oxides that include alumina and silica. In some embodiments, a certain amount of stabilizers for the alumina and a certain amount of promoters are also added to the wash coat. Typically, there is no difference between the commercially purchased wash coat and the created wash coat. At a step **415**, the dispersion is mixed with the wash coat. At a step **420**, a cylindrical-shaped ceramic monolith is obtained. The monolith contains a large proportion of cordierite since cordierite has a high resistance to thermal shock. In some embodiments, the monolith is a honeycomb structure. A cross-section of the monolith preferably contains 300-600 channels per square inch. The channels are preferably linear square channels that run from the front to the back of the monolith. At a step **425**, the monolith is coated with a layer of the wash coat. This can be achieved by dipping the monolith in the wash coat. The channels of the monolith are also coated with a layer of wash coat. Since the wash coat contains the nano-particles, nano-platinum particles are also on the surface of the monolith. At a step **430**, the monolith is dried. At a step **435**, the monolith is calcined. The calcination bonds the components of the wash coat to the monolith by oxide to oxide coupling. In addition, the calcination allows the nano-active materials to strongly attach to the nano-supports because the nano-supports have a partially reduced alumina surface. As such, the advanced DOC catalyst is formed.

FIG. **5** illustrates a second inventive process **500** for creating the advanced DOC catalyst in accordance with the present invention. At a step **505**, nano-active materials are pinned or affixed to nano-supports, forming nano-materials, by using a high temperature condensation technology such as a plasma gun. In some embodiments, the nano-active materials are gaseous platinum atoms and the nano-supports are some form of alumina, such as aluminum plus oxygen. Since nano-active materials are strongly attached to nano-supports, movement or coalescing/conglomeration of the nano-active materials is limited, prevented, or both. The nano-particles are then combined with a liquid to form a dispersion. At a step **510**, a wash coat is obtained. The wash coat is commercially purchased or is made. The wash coat is made by using micron-sized oxides that include alumina and silica. In some embodiments, a certain amount of stabilizers for the alumina and a certain amount of promoters are also added to the wash coat. Typically, there is no difference between the commercially purchased wash coat and the created wash coat. At a step **515**, a cylindrical-shaped ceramic monolith is obtained. At a step **520**, the monolith is coated with a layer of the wash coat such as via dipping. As such, the channels of the monolith are also coated with a layer of the wash coat. At a step **525**, the monolith is dried. At a step **530**, the monolith is calcined. At a step **535**, the dispersion is applied to the monolith via dipping. At a step **540**, the monolith is dried. At a step **545**, the monolith is calcined. The calcination bonds the components of the wash coat to the monolith by oxide to oxide coupling. As such, the advanced DOC catalyst is formed

In order for the wash coat to get good bonding to the monolith, both pH level and viscosity of the wash coat must be in a certain range. Typically, the pH level must be between four and five to achieve oxide-oxide coupling. If the pH level is too low, then the viscosity is too high; as such, the wash coat is a paste instead of a slurry. If the pH level is too high, then the viscosity is too low; as such, even after calcination, the wash coat does not bond to the monolith. Although the use of nanomaterials applied to the advanced DOC catalyst is described, the use of nanomaterials is able to be applied to the DPF and the NOx reduction technology used in the diesel engine. Other catalysts in the automation space are also contemplated.

Gas Engines

A gas engine cycles from oxygen rich to oxygen poor (e.g., an oxidizing state to a reducing state). As such, a conventional catalytic converter for gas engines includes an oxidation catalyst and a reduction catalyst. The reduction catalyst is a first stage in the conventional catalytic converter. The reduction catalyst uses platinum and rhodium to help reduce NOx emissions. For example, rhodium catalyzes CO and NO_2 to N_2 and CO_2. The oxidation catalyst is a second stage in the conventional catalytic converter. It reduces unburned hydrocarbons and carbon monoxide by oxidizing them using platinum and palladium. For example, platinum catalyzes CO and O_2 to CO_2 and catalyzes H_aC_b and O_2 to CO_2 and H_2O. Palladium catalyzes H_2 and O_2 to C_2O. The oxidation catalyst aids reaction of the carbon monoxide and hydrocarbons with the remaining oxygen in the exhaust pipe. Accordingly, the gas engine uses a three-way catalytic converter to reduce the three harmful compounds.

Conventional methods of creating the three-way catalytic converter use micron-sized catalytic materials and supports, as discussed above. In addition, the conventional methods use multiple dippings to get palladium ions, rhodium ions, and platinum ions on the monolith since a dip that includes, for example, palladium ions and rhodium ions would produce palladium-rhodium alloys, which is not beneficial in certain conditions and/or applications. Embodiments of the present invention use nano-sized catalytic materials and supports instead. In additions, embodiments of the present invention allows a dip to include palladium ions, rhodium ions, and platinum ions without creating palladium-rhodium alloys, because the different ions have different solid phases.

Methods of creating the advanced three-way catalyst for gas engines are similar to the methods of creating the DOC as discussed above. The difference is in the initial steps **405** and **505** of FIGS. **4**-**5**, respectively. Specifically, instead of using just gaseous platinum atoms in the dispersion, gaseous palladium atoms and gaseous rhodium atoms are also used.

FIG. **6**A illustrates a first method of creating the dispersion in accordance with the present invention. Catalyst materials include platinum **615**, palladium **620**, and rhodium **625**. Other catalyst materials are contemplated. Carrier material includes alumina **630**. The catalyst materials **615**, **620**, **625** and carrier material **630** are mixed in a plasma gun. After vaporizing the catalyst materials and carrier material to form a vapor cloud and quenching the vapor cloud, the vapor cloud precipitates nano-particles. FIG. **6**B illustrates a nano-particle **600** in accordance with the present invention. The nano-particle **600** comprises a nano-active material **610** and a nano-support **605**. Since the plasma gun is extremely chaotic, the catalyst materials form into an alloy. As such, the nano-active material **610** is an alloy. Since a ratio of the nano-active material **610** consisting of platinum, palladium, and rhodium, depends on an initial ratio of each of the catalyst materials used, different forms of alloys are formed on the nano-support **605**. The nano-particles **600** are combined with the liquid to form the dispersion.

FIG. **7**A illustrates a second method of creating the dispersion in accordance with the present invention. Instead of mixing platinum **615**, palladium **620**, rhodium **625**, and alumina **630** in the plasma gun, each of the catalyst materials are separately mixed with alumina **630** in the plasma gun. As such, after vaporizing and quenching each of the catalyst materials, three different nano-particles are formed. A collection of the different nano-particles are combined with the liquid to form the dispersion. The three different nano-particles are illustrated in FIG. **7**B. A first nano-particle **600'** is a platinum nano-active material **635** on the alumina nano-support **605**. A second nano-particle **600"** is a palladium nano-active material **640** on the alumina nano-support **605**. A third nano-particle **600'"** is a rhodium nano-active material **645** on the alumina nano-support **605**. A size of the nano-active material is able to be controlled based on a quantity of the nano-active material that was initially placed in the plasma gun. Concentration of each different nano-particle **600'**, **600"**, **600'"** is able to be individually and/or collectively controlled.

After creating a dispersion either using the first method (as illustrated in FIG. **6**A) or the second method (as illustrated in FIG. **7**A), the first inventive process **400** continues at a step **410** and the second inventive process **500** continues at a step **510**, as illustrated in FIGS. **4**-**5**, respectively.

While the invention has been described with reference to numerous specific details, one of ordinary skill in the art will recognize that the invention can be embodied in other specific forms without departing from the spirit of the invention. Thus, one of ordinary skill in the art will understand that the invention is not to be limited by the foregoing illustrative details, but rather is to be defined by the appended claims.

We claim:

1. A catalytic converter comprising:

a honeycomb structure; and

a washcoat layer on the honeycomb structure comprising nano-particles and micron sized oxide particles, wherein the nano-particles are plasma-generated;

wherein the nano-particles consist of a single nano-active material component and a single nano-support component.

2. The catalytic converter of claim **1**, wherein the nano-active material comprises platinum.

3. The catalytic converter of claim **1**, wherein the nano-active material comprises palladium.

4. The catalytic converter of claim **1**, wherein the nano-active material comprises rhodium.

5. The catalytic converter of claim **1**, wherein the nano-active material comprises an alloy.

6. The catalytic converter of claim **1**, wherein the nano-support comprises alumina.

7. The catalytic converter of claim **1**, wherein the nano-support comprises a partially reduced alumina surface.

8. The catalytic converter of claim **1**, wherein the micron sized oxide particles comprise alumina.

9. The catalytic converter of claim **1**, wherein the nano-active material comprises an alloy comprising platinum and palladium.

10. A cordierite substrate in a catalytic converter comprising:

a. a first type of plasma-generated nano-particles consisting of a single first nano-active material component and a single first nano-support component; and

b. a second type of plasma-generated nano-particles consisting of a single second nano-active material component and a single second nano-support component.

11. The cordierite substrate of claim **10**, wherein the first nano-active material comprises platinum.

12. The cordierite substrate of claim **10**, wherein the first nano-support comprises alumina.

13. The cordierite substrate of claim **10**, wherein the first nano-support comprises a partially reduced alumina surface.

14. The cordierite substrate of claim **10**, wherein the first type of nano-active material comprises palladium.

15. The cordierite substrate of claim **14**, wherein the first nano-support comprises alumina.

16. The cordierite substrate of claim **10**, wherein the second nano-support comprises a partially reduced alumina surface.

17. The cordierite substrate of claim **10**, wherein the second nano-active material comprises rhodium.

18. The cordierite substrate of claim **10**, wherein the second nano-support comprises alumina.

19. The cordierite substrate of claim **10**, wherein the third nano-support comprises a partially reduced alumina surface.

20. The cordierite substrate of claim **10**, wherein the first nano-active material comprises palladium, and the second nano-active material comprises rhodium.

21. The cordierite substrate of claim **10**, further comprising a third type of plasma-generated nano-particles comprising a third nano-active material and a third nano-support.

22. The cordierite substrate of claim **21**, wherein the first nano-active material comprises palladium, the second nano-active material comprises rhodium, and the third nano-active material comprises platinum.

23. The cordierite substrate of claim **21**, wherein the first nano-support and the second nano support comprise alumina.

24. A catalytic converter comprising:

a honeycomb structure;

oxidation nano-particles on the honeycomb structure, wherein the oxidation nano-particles comprise particles having a single oxidation nano-active material component and a single nano-support component; and

reduction nano-particles on the honeycomb structure, wherein the reduction nano-particles comprise particles having a single reduction nano-active material and a single nano-support component;

wherein the oxidation nano-particles and reduction nano-particles are plasma-generated.

25. The catalytic converter of claim **24**, wherein the oxidation nano-particles and reduction nano-particles are part of a washcoat layer formed on the honeycomb structure.

26. The catalytic converter of claim **24**, wherein the oxidation nano-particles are part of a first washcoat layer on the honeycomb structure and reduction nano-particles are part of a second washcoat layer formed on the honeycomb structure.

27. The catalytic converter of claim **24**, wherein the oxidation nano-active material comprises palladium.

28. The catalytic converter of claim **24**, wherein the oxidation nano-active material comprises platinum.

29. The catalytic converter of claim **24**, wherein the reduction nano-active material comprises rhodium.

30. The catalytic converter of claim **24**, wherein the nano support of the oxidation nano-particles comprises alumina.

31. The catalytic converter of claim **24**, further comprising micron sized oxide particles on the honeycomb structure.

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